NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE EFFECT OF ALCOHOL INGESTION
ON
SHORT TERM MEMORY AND ATTENTION

by

Christopher Michael Grauert

Thesis Advisor: D. E. Neil

Approved for public release; distribution unlimited.

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be overcome by attention. Analysis of the data collected from 10 subjects showed that alcohol adversely affected Short Term Memory in all three delay modes, while motivation had no effect in overcoming this Short Term Memory degradation due to alcohol ingestion.

The Effect of Alcohol Ingestion
on
Short Term Memory and Attention

by

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ABSTRACT

Using a serial short term memory task, subjects were required to respond to stimuli presented one-back, two-back, and three-back from a random sequence of four different symbols before alcohol ingestion, after alcohol ingestion and again after alcohol with motivation. The purpose of the experiment was to determine whether alcohol had an adverse effect on Short Term Memory and, once intoxicated, whether the degradation of Short Term Memory could be overcome by attention. Analysis of the data collected from 10 subjects showed that alcohol adversely affected Short Term Memory in all three delay modes, while motivation had no effect in overcoming this Short Term Memory degradation due to alcohol ingestion.

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I. INTRODUCTION

A. THE PROBLEM

The degradation of human performance due to alcohol ingestion is a well known phenomena and has been the subject of extensive research over the past 20 years by such experimentors as Mello [1955], Hutchinson [1964] and Ryback [1970]. This intensive effort spent on alcohol research certainly is justified considering these appalling current statistics which underscore the lethal potential of this drug [All Hands Magazine, Nov. 1974]:

(1) - 10,000,000 alcoholics in the U. S. alone, which is 20 times the number of heroin addicts.

(2) - Alcohol related problems (accidents, lost production, medical care, etc.) cost Americans $15,000,000,000 per year.

(3) - Drunk driving causes about 26,000 lives per year.

(4) - 70% of adults over 18 drink; 8% of these will become alcoholics.

(5) - Among alcoholics

only 3% are skidrow bums

75% are male

97% are employed

50% attended or graduated from college

45% are professionals

(6) - 25% are white collar workers.

(7) - Alcoholics require 4 times as much medical care.

(8) - Alcoholics average 22 days absenteeism a year.

(9) - Auto accidents are 7 times more frequent with alcoholics.

(10) - Alcoholism is the third leading cause of death in the U. S. after heart disease and cancer.

One field of military operations particularly hindered by the associated problems of alcohol abuse is aviation. The safe, successful completion of each aircraft mission depends upon not only the professional skills of the aircrew, but also upon the performance of the maintenance personnel. In 1959, for example, 43% of all fatal aircraft accidents involved alcohol [Ryan and Mohler, 1972]. This led to the publication of Federal Aviation Regulation (FAR) 91.11 in 1960 which stated that "no person may act as a crewmember of an aircraft while under the influence of intoxicating liquor." After FAR 91.11 was modified in 1970 to read "no person may act as a crewmember of an aircraft within 8 hours after the consumption of any alcoholic beverage," the percent of alcohol related aircraft accidents has dropped and stabilized at 20%.

Besides the familiar loss of coordination and sound judgement subsequent to alcohol ingestion, there has been a substantial amount of research performed on the effect of alcohol upon memory. Obviously, an unobstructed memory is essential to the safe operation of an aircraft. If a pilot consumes even moderate amounts of alcohol, he may have difficulty remembering even simple instructions for more than 5 minutes. This was demonstrated by Ryback, Weinert,

and Fozard [1969] when they found a significant memory decline in pilots who were required to recall standard take-off and landing checklists after ingesting alcohol dosages as small as 4 ounces. Therefore, operation of an aircraft while under the influence of even small amounts of alcohol seriously endangers the lives of the entire crew as well as the loss of a multi-million dollar aircraft. This study further demonstrated that moderate doses of alcohol which would disrupt Short Term Memory would also detrimentally affect time perception. For example, speed of an oncoming aircraft or runway depends upon the pilot's subjective judgement of the time rate of change of displacement of the other object, as shown by Ryback [1970]. His pilot subjects consistently initiated both mechanical functions (flaps, landing gear, etc.) and flight path corrections at improper times while under alcohol influence. Therefore, the disruption of time perception has many dangerous implications for flying safety.

Billings, Wick, et.al. [1973] had experienced pilots fly instrument approaches under various alcohol ingestion levels. They discovered a definite narrowing of attention and decrease in channel capacity (i.e. the quantity of incoming stimuli the subject is capable of processing) while the pilots consumed increasing amounts of alcohol. Although most pilots, even while intoxicated, were able to position their aircraft properly at minimums, they did so at the expense of all the secondary tasks necessary for safe flight such as fuel state

monitoring and radio communications. Since a signficant number of flying accidents are due directly to maintenance crew mistakes, the dangers to aviation safety caused by the disruption of memory by alcohol consumption equally applied to them. Decision making, sensory perception, motor skills, and disposition are all affected by alcohol ingestion as shown by Kalin (1964) and Tamerin (1971).

Although the effects of large doses of alcohol on human coordination and judgement are well known, the present study was designed to test the effect of attention upon human short term memory performance once in the alcoholically intoxicated state. Accident statistics indicate however that moderate doses of alcohol and the requirement for skilled performance are incompatable.

The U. S. Navy has recently commenced a large scale alcohol drug awareness program with the intent of widely publicizing the inherent dangers of alcoholic consumption. Like any organization, the Navy suffers from alcohol related problems such as absenteeism, below-par performance, hospitalization and loss or damage of human lives and equipment, which represents an unnecessary deterrent in terms of efficiency and economic drain of scarce financial resources. The more information the Navy can muster concerning the nature of alcohol, the greater the chance it has to deal with the problem realistically.

The purpose of this study, therefore, is twofold:

(1) to investigate the possible effect of alcohol upon Short Term Memory, using tasks of varying degrees of difficulty.

(2) to investigate the possible effect of the phenomena of attention in overcoming human performance degradation due to alcohol ingestion.

B. BACKGROUND RESEARCH ON ALCOHOL

A large proportion of the population has imbibed in the "pleasures" of alcohol to varying degrees - ranging from a glass of wine to enhance a meal to an all night cocktail party. Thus most people have undoubtedly experienced, to some degree, the effects of alcohol upon normal human functioning.

What is commonly referred to as alcohol is more precisely a chemical compound known as ethyl alcohol or ethanol. This compound, with the chemical formula CH_3CH_2OH, was discovered to possess the ability to induce euphoria, sedation and intoxication as early as the prehistoric times of the Egyptian Pharohs. Its precise origin of discovery is buried in antiquity, but the presence of wine and beer is well attested in archaeological records of the oldest civilizations. Alcohol is produced by the fermenting action of enzymes derived from yeasts and various carbohydrates such as those found in grapes, barley, grains, etc.

Prehistoric man, probably accidently, discovered that any fruits or berries left in a warm atmosphere and thus exposed to the action of airborne yeasts, fermented into crude wine. The mood changing effects of these fluids were regarded as useful and beneficient. In his attempts to appease the

divine powers which he perceived to determine his fate, early man offered sacrifices to these divinities, in the form of water, milk and honey. In many subsequent cultures, such as the Greeks and Romans, wine and beer replaced water as the sacrificial gift offered in religious ritual. This is hardly surprising, for alcoholic beverages were obviously more suitable for evoking moods of release, mystification and ecstasy that were sought as a way to communicate with powers that were invisible and beyond knowing. The secularization of alcohol was undoubtedly related to the fact that its traditional role in religion tended to impart a desired aura of sancitity or solemnity to its use on nonreligious occasions. Alcoholic beverages became mandatory not only in worship and in the practice of medicine, but also to solemnify formal councils, ratify contracts, commemorate festivals, display hospitality, stimulate warmaking, celebrate peacemaking, and confirm the important rites of life-births, marriages, and funerals [Alcohol and Health, 1974].

Although the effects of alcohol consumption were well known throughout the ages, there was little scientific research done on alcohol prior to 1860. What was commonly known about the subject was based mostly upon a few experiments and popular tradition. Alcohol was wrongly regarded as a stimulant, and able to create and sustain body warmth. It was also considered to be a legitimate food, capable of being burned and oxidized by the body and converted to heat and energy.

However, in 1866 the first myth about alcohol was disproved by Sir Ben Richardson [Timberlake, 1963], who conducted experiments that proved that alcohol actually lowered body temperature. The familiar warm sensations experienced after alcohol ingestion are very illusionary. Instead, Richardson discovered that alcohol paralyzes the blood vessel nerves within the body, causing them to dialate thereby allowing more blood to reach the surface of the body where it is quickly cooled.

Even more important were the findings of Kraeplin in 1893: that alcohol was a depressant and not a stimulant. Through laboratory tests he showed that alcohol, rather than stimulating the brain and Central Nervous System (CNS), acted rather as an anesthetic. He demonstrated that even extremely small amounts of alcohol (e.g. 1 ounce) causes significant depressant action.

In the early 1900's, experiments showed that the toxic action of alcohol exerts a pronounced influence upon the higher decision making centers of the brain and gradually progresses to the lower and less complex brain centers [Wechsler, 1941]. Regardless of quantity, alcohol degrades those mental processes such as perception, stimulus-response connections, information processing, judgement, and eventually the more elementary motor reactions.

Mello [1973] showed that excessive alcohol ingestion is associated with two types of impaired memory function. The first is the familiar temporary global memory loss, commonly

called mental blackout. The second is the fragmentary loss of recall of events called the disassociative state. The exact mechanisms involved in these alcohol induced memory impairments is still unknown.

A research survey by Goodwin /̲1969_7 indicated that alcohol ingestion, which is severe enough to cause information loss to Short Term Memory (STM), via obscured perception, would also deny storage of this information in Long Term Memory (LTM). This, in turn, causes a period of global memory loss. Since STM and LTM are sequential processes required for subsequent information retrieval, the degradation of STM affects what is store in LTM.

Ryback and Fozard /̲1971_7 presented a picture recognition task to a group of nonalcoholics after a moderate amount of alcohol was consumed. The result was a decline in recollection performance when the number of pictures between the first and second presentation was increased, suggesting that alcohol affected registration as well as attention mechanisms.

Departing slightly from the findings of Ryback and Fozard, Tamerin and Weiner /̲1971_7 found that the major defect in the memory function at various levels of intoxication is not in the registration phase of presented stimuli but rather in the retention. In the intoxicated subjects, memory traces became extremely fragile: that is, the traces were easily disrupted or subsequently lost in a few moments by external interfering stimuli, causing the familiar difficulty (or inability) to recall events occurring while inebriated.

In their alcohol experiments, Ekman, Frankenhaeuser, et.al. [1962] supported the concept of alcohol amnesia. Alcohol amensia is produced after either an acute or a prolonged rise in Blood Alcohol Content (BAC), during which time no LTM storage takes place, since STM is severaly disrupted. Thus, memory occurring during the drugged state cannot be recalled. During alcohol amnesia, memory of recent events is disturbed, but past events remain unhindered.

Kalin [1964] performed work with subjects to determine the relationship between moderate alcohol consumption and memory. His subjects consumed alcohol in social situations as opposed to a laboratory environment. His results showed a linear decrease in STM as a function of amount of alcohol consumption. There was, however, no decrease in STM or LTM for items stored before drinking. These findings opposed the alcohol amnesia concept. The more the subjects consumed, the better they were able to recall information learned immediately prior to drinking. In addition, the strong linear relationship between alcohol consumption and decrease in STM subsequent to drinking suggested that alcohol amnesia (with indeterminate relation to amount consumed) is not a common occurance during social drinking. These results indicated that loss of memory is very gradual and strongly dependent upon the amount of alcohol consumed.

Ryback [1971, 1973] studied the findings of Kraepelin who found that impairment of performance on memory tasks caused by large doses of ethanol was frequently but briefly

preceeded by improved performance. The seemingly paradoxical properties of facilitation and disruption of STM are a function of alcohol dosage. Facilitation occurred very briefly and then only after a very small amount of alcohol ingestion. Ryback showed that subsequent higher doses of alcohol, however, tend to selectively disrupt STM and thus produce alcohol amnesia.

Hutchinson, Tuchtie, Gray, and Steinberg [1964] presented their subjects with a test battery containing several tasks of varying difficulty. Their data supported the contention that subjects under the influence of alcohol demonstrated learning deficiencies and they had difficulty in acquiring the mental associations to be retained over time. Hutchinson's explanation for this memory impairment was that alcohol has an effect upon retention by virtue of altering the process of decay or interference once the associations have been formed. These findings agreed with those of Wechsler [1941] who found that the effect of alcohol is to lower the functioning level of nearly all mental abilities. The degree of impairment is a function of amount consumed, time of ingestion, and complexity of the task. He found that the main memory defect is in the area of retention and the acquisition of new stimulus-response associations.

In recent years, there have been several studies undertaken to investigate the effects of alcohol upon attention. Pearson [1968] reported that monitoring performance improved with the amount of time on the task, a finding which contrasts with traditional concepts of skill fatigue.

Ryback [1973] tackled the problem of attention and intoxication by defining various "activation levels."

> The concept is that if activation level is too low then the hypothetical memory traces do not preseverate and, hence, do not consolidate. If activation level is at some optimum middle value then preservation takes place and consolidation occurs. If activation level is too high, differential preservation of the memory does not occur efficiently due to the unfavorable signal to noise ratio, and consolidation of the trace does not occur.

Ryback therefore suggests that optimal learning and memory occur in the range from the normal daily cycle to the moderate excitable stage of increased CNS excitement, while disruption or inhibition of learning and memory occurs at either extreme of increased (convulsion stage) or decreased (anesthesia stage) CNS excitability, as is shown in Figure 1. For example, motivation which is so extreme as to create a hyper excitable or convulsion state, causes anxiety or "neural noise" which overwhelms the thought processes to the extent of disruption of learning and memory. This phenomena occurs during "stagefright" or forgetting previously well known facts while under pressure during an examination.

In summary, the wide ranging field of alcohol research shares the common element of investigation of various types of impairment due to alcohol ingestion. This impairment, causing subsequent degradation of human performance, can manifest itself in the form of perceptual, stimulus-response connections, judgement, motor reactions, information processing, etc. Of particular interest here is the effect of alcohol

EXCITABILITY STATE	DEGREE	BEHAVIORAL MANIFESTATION	PERFORMANCE CAPACITY
INCREASED	Severe Mild	Convulsion	Activation Too High
	Hyper Moderate Mild	Excitable	Disruption of Learning and Memory
CNS EXCITABILITY	NORMAL DAILY CYCLE		Hypothetical Range of Optimal Activation Level
DECREASED	Sedation	Anesthesia	Activation Too Low
	Delirium		
	Surgical		Inhibition of Learning and Memory
	Mudullary Paralysis		

Figure 1. RESULTS OF CNS EXCITATION AND DEPRESSION
/Adapted from Ryback, 1973/

upon STM and related problems such as temporary or global memory loss, registration or retention phases, and facilitation or disruption. Also, the effect of attention on human performance via motivation is a relatively unexplored area but has been under the investigation of Ryback whose theory proports the link between the two is explained by means of activation levels.

C. SEQUENCE AND EFFECTS OF ALCOHOL INGESTION

Most substances after consumption undergo a process of digestion before being absorbed into the blood stream. Alcohol, however, needing no digestion, is absorbed directly and quite rapidly into the blood stream from the stomach and small intestine, especially if consumed at a time remote from the ingestion of food. The rate of absorption depends upon the type of alcoholic beverage consumed. For example, the carbonation in beer, as well as the mix in diluted cocktails, slow the absorption process, whereas straight spirits act very fast in getting into the circulatory system.

Once in the blood stream, alcohol is distributed throughout all the tissues and fluids of the body. It tends to concentrate in those parts of the body which have the most blood vessels and highest water content. The most immediate and obvious result of alcohol ingestion is its effect upon the CNS. McFarland [1953] showed that the apparent stimulating affect we feel after that first martini is actually caused by the paralysis of the inhibitory centers which control

the reticular system which in turn affects information processing, decision making, learning and perceiving. Freed from this control, the cortex functions in a less organized manner, degrading the motor functions and alertness, and removing the suppressive bonds of our inhibitions. This apparent stimulating response to alcohol also comes from the exciting influences of festivity which frequently accompany social drinking.

Dosage of alcohol consumption is considered in terms of milligrams percent (mg.%). Dividing mg % by 1000 gives the Blood Alcohol Content in percentage terms. A BAC of .1 constitutes legal drunkness in California. Table I equates levels of BAC to symptoms after ingestion. The approximate intake values are highly dependent upon body weight and rate of ingestion.

As the alcohol ingestion increases, emotions and impulses are freed from restraints normally controlled by the inhibiting system and erratic behavior results. Judgement and responsibility are blurred and functions of the cerebral cortex are impaired. As a result, muscular skills and sensory ability are degraded. Eventually, there is a loss of realization of the extent of ones impairment, often accompanied by the loss of STM as previously documented.

Elimination of alcohol from the body takes place primarily through oxidation in the liver, where alcohol is metabolized into an acetate utilizable for energy and finally converted

BAC (%)	INTAKE (OZ.)	INFLUENCE	SYMPTOMS
.01 - .05	1	SOBRIETY	Normal
.03 - .12	2	EUPHORIA	Talkativeness Diminution of attention Decreased inhibitions
.09 - .25	8	EXCITEMENT	Emotional instability Impairment of memory Loss of critical judgement Muscular incoordination
.18 - .30	10	CONFUSION	Disorientation Exaggerated emotional states Impaired balance Slurred Speech
.27 - .4	15	STUPOR	Apathy Decreased response to stimuli Impaired consciousness Inability to walk
.35 - .50	20	COMA	Subnormal temperature Unconsciousness No reflexes
.45 +	20 +	DEATH	Death (From Respiratory Paralysis)

Table I. LEVELS OF ALCOHOL TO SIGNS AND SYMPTOMS

to carbon dioxide and water. The liver is capable of oxidizing approximately 1/3 oz. of alcohol per hour. Only about 5% of ingested alcohol is eliminated unmetabolized via urine, skin and lungs. Any additional alcohol in the body queues up awaiting elimination and intoxication results. Despite many beliefs to the contrary, no technique such as exercise has yet been uncovered which increases the rate at which the body burns alcohol. The traditional remedy of black coffee stimulates the brain with caffeine, but does not increase the rate of alcohol oxidation.

After finishing his last cocktail, the drinker is high and has lost his sense of equilibrium. This results from his cerebrum being depressed, causing his psychomotor activity to diminish, [Newman, 1970]. He is relaxed, less frightened, and less anxious. However, as soon as his BAC starts to fall, the sedative effect of alcohol is lost. Rather than return to his normal, preintoxicated state, the psychomotor activity level increases. An agitating effect starts to gather momentum and the individual begins to feel more tense than he was before he commenced drinking. This effect is, of course, the "hangover," and it may last anywhere from 12-24 hours after drinking, depending upon amount of alcohol consumed. The hangover victim feels tired because he is tired - his hyperactivity as a result of loss of normal inhibitions and control on behalf of the brain have taken their toll on the muscles of the body, rendering him virtually incapable of normal mental and physical functioning.

D. THEORIES OF SHORT TERM MEMORY

The most widely accepted theory of memory contains two principle components: Short Term Memory (also known as "recent" or "primary" memory) which functions during the rearward portion of the present space of time, and Long Term Memory (also known as "distant" or "secondary") which operates during the recall of events which have already once dropped from consciousness.

Broadbent [1958] supported the idea that one type of storage mechanism is involved in STM; that is in remembering or being otherwise affected by an event just recently experienced. A different type is involved in LTM; in the recall of traces established by repetitive learning experiences or habit. He contended that there are three principle differences between the two types of memory, and defines them as follows:

1. STM involves activity traces, while LTM involves structural traces.
2. STM involves autonomous decay, while LTM involves irreversable, non-decaying traces.
3. STM has a fixed capacity that is subject to overload and consequent loss of elements stored in it, while LTM is infinitely expansible, with failure of retrieval attributable mainly to incompleteness of the cue to retrieval or to interference from previously or subsequently learned associations.

The key link between LTM and STM is the phenomena of rehearsal.

1. Rehearsal

Rehearsal is an inner, repetitive speech in which items to be retained are vocally or subvocally repeated by subjects in order to strengthen their trace and increase their probability of recall.

Rehearsal is also the decoding of visual stimuli into acoustical properties. It transfers a recently perceived item from one memory store of limited capacity (STM) to another more suitable and permanent store (LTM) from which it can be retrieved at a much later time. Thus, unfamiliar material must be deliberately rehearsed if it is to be retained. The likelihood that an item in a list will be recalled increases with the amount of time available for its rehearsal. This was demonstrated by Cherry [1953] who gave his subjects a verbal shadowing task. Upon completion of the experiment, his subjects were unable to recall the content of the shadowed text, since no rehearsing (and consequently no attention) could be afforded the shadowed words; thus their traces quickly vanished from their STM.

Material that is not rehearsed, either vocally or sub-vocally, is rapidly lost, regardless of presentation rate. Waugh and Norman [1965] believed that all stimuli enter STM, where they are either rehearsed or forgotten as in Figure 2. Their conclusions reveal that the probability of an item in STM being recalled depends upon:

1. the number of items preceived,
2. the amount of rehearsal time,

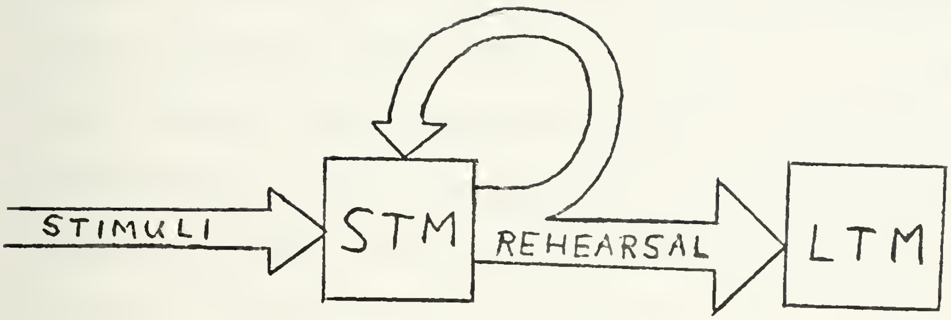

Figure 2. WAUGH AND NORMAN'S REHEARSAL MODEL

3. how many old items have been recalled between a particular item's presentation and attempted recall.

Past research [e.g. Miller, 1956] has shown that the maximum number of unrelated digits that can be correctly recalled after one presentation, even with rehearsal, is ten. In addition, Waugh and Norman observed that subjects nearly always recalled the most recent item in a series of digits regardless of the length of the series. They concluded that the span of STM is limited by the inability to rehearse the early items in the sequence while attempting to store the latter ones. Their studes attempted to resolve the problem

of why an unrehearsed item is so quickly forgotten. They supported the interference theory which holds that physiological traces are written over and obliterated by subsequent traces of items which follow. This is in contrast to the decay theory, which proports that trace retention is simply a function of time. They also found that rehearsal may transfer an item from a very limited primary memory store to a larger and more stable secondary store; that is, from STM to LTM.

Melton [1963] also found that interference or proactive inhibition was greatly underestimated as a source in forgetting, because decay of memory traces can be postponed by rehearsal. Decay of a specific trace begins whenever rehearsal is prevented by distraction or overloading of STM.

In contrast, Brown [1958] studied the effect of time for rehearsal of a set of items. He concluded that recirculation of information through STM merely delays the onset of decay, but does not strengthen the trace. Unless some effort was made to retain traces via rehearsal, memory traces will decay. Once the rehearsal ceased, the item rapidly decays with the passage of time.

Another phenomena which has been under recent study is channel capacity, which is the upper limit on the capacity of the subject to match his responses to presented stimuli. Although STM is generally regarded as a limited storage, Miller [1956] proposed that STM capacity could greatly be increased through the process of chunking. This process

involves the encoding of bits of information into chunks according to previously learned classifications, thereby allowing the subject greater information storage capacity in STM. Since the span of STM imposes severe limitations on the amount of information we are able to receive, process, and remember, organizing the input stimulus into a series of chunks allows the avoidance of this informational bottle-neck.

E. THEORY OF ATTENTION

The capacity of the human to deal with incoming information is severely limited. Of all the countless stimuli received continuously by the senses, only a very small portion of them are selected for further processing. The phenomena of attention determines this limitation and selection process and is therefore closely related to STM. Attention is a voluntary means by which we elevate our receptors to a high state of readiness for stimuli reception. In fact, confident expectation of a certain stimuli may often actually cause us to see or hear it, regardless of its absence or presence.

James [1890] believed that attention is the taking possession by the mind of one out of several objects. Its essence is focalization and concentration. It implies with-drawal from some things in order to deal effectively with others. An object once attended will remain in memory, while one inattentively allowed to pass will leave no trace behind.

One of the classic problems yet to be settled in this area of attention is the determination of the number of items to which we can simultaneously attend. This of course depends upon the difficulty of the task, but most researchers agree that our selective process is limited to one channel. This is supported by the familiar cocktail party phenomena. If a person attempts to listen simultaneously to two different conversations, he may do so, but only by means of rapidly switching or time sharing his attention from one conversation to the other. Therefore he is, in effect, still only using one channel and runs the risk of missing an important item of one conversation if it is presented while he is attending to the other one.

Broadbent [1958], one of the most significant contributors to the theory of attention, suggested that the limit to our ability to perceive competing messages is perceptual: we are able to analyze and identify only a limited amount of the information which arrives at our sensory inputs. His theory was that the brain contains a selective filter which can be tuned by means of attention to accept the desired message and reject all others. Thus all stimuli not attended to are filtered out and lost. It is precisely attention which directs the focus of our perception onto those inputs we wish to accept. He supported the single channel theory and believed that a STM System prevented loss of information about the immediate past history of the unselected channel. Broadbents Filter Theory is shown in Figure 3.

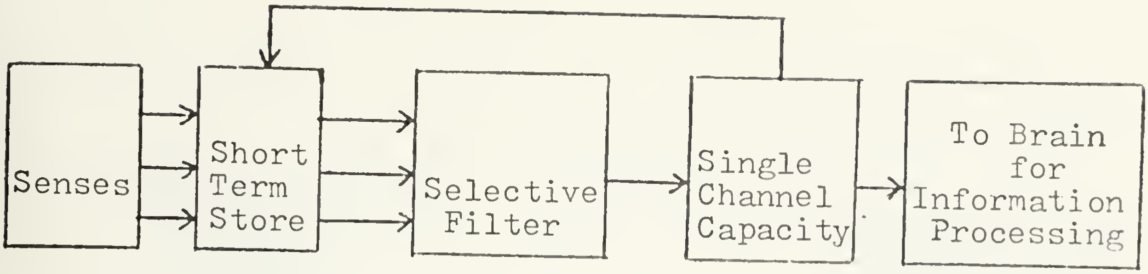

Figure 3. BROADBENT'S FILTER THEORY

Norman [1969] proposed an alternative approach to Broadbents filter theory. He believed that the selective process among alternative channels itself requires complex processing. Broadbent's filter theory is fine so long as the selection can be performed by looking for simple, physical differences among incoming stimuli. However, his theory breaks down when dealing with complex stimuli. Norman's model for the selection process (Figure 4.) holds that both physical inputs as well as pertinence of information determine what will be selected for further processing. Physical inputs pass through the sensory system and initial filters before being represented in the storage system. Simultaneously, the analysis of previously encountered material, coupled with expectations, determine the class of events assumed to be most pertinent at the moment. That material which receives the greatest combined representation is selected for further attention.

A general problem in the study of alcohol and memory is the type of task used. The type of memory explained in a task depends not only on the time interval between presentation and testing but also on the characteristics of the task. The chunks of information (as proposed by Miller) in a task can

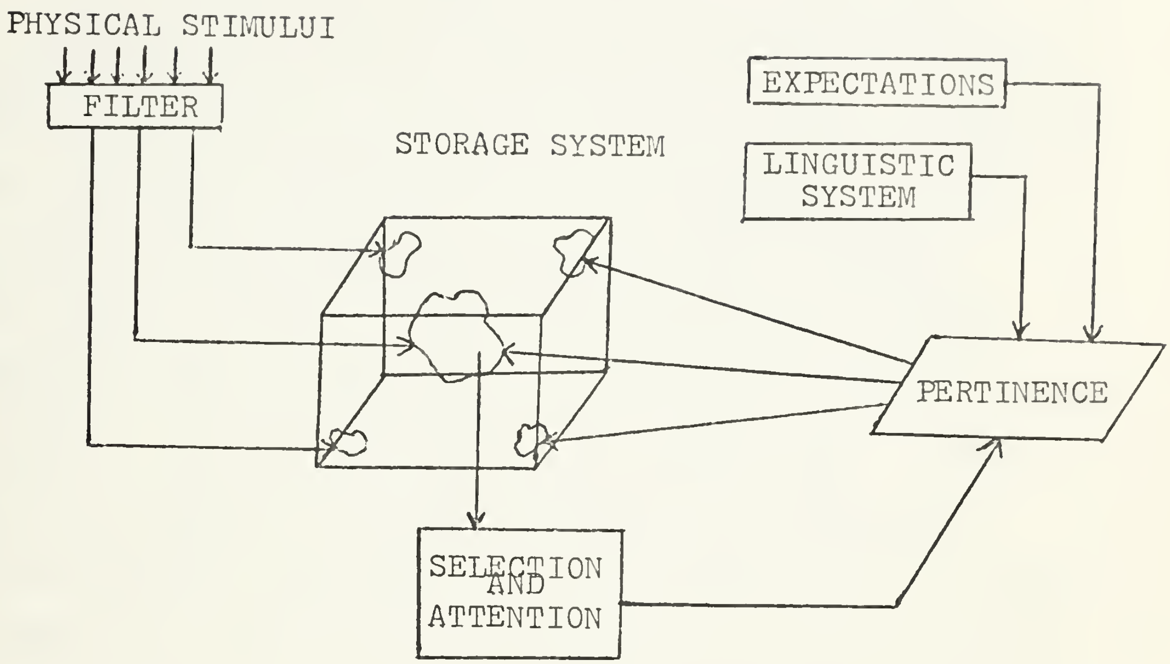

Figure 4. NORMAN ATTENTION MODEL

vary in difficulty and thus the actual amount of information may be independent of its length. Tasks which require repetition to reach criteria necessitate that some form of memory storage takes place. Thus, an ideal task for studying the effects of alcohol on STM should possess the following characteristics.

1. A simple memorandum in which performance does not heavily depend upon an individual's proficiency or adaptability.
2. A continuous task in which the length and amount of intervening material varies so that STM may be assessed before and after alcohol ingestion.

3. A range of difficulty within comparable tasks which would permit individual variations in performance and allow for quantitative evaluation of the results.

Subsequent analysis of the data as well as observations of subjects' performance hopefully will shed light upon such issues as time decay versus interference decay, channel capacity and the intrinsic link between rehearsal and STM. In addition, other phenomena such as attention and time sharing will influence subject performance on a given task. Whether attention is capable of still selecting out a few desired stimuli for further information processing while in an intoxicated state is a matter for investigation, as is the question of whether attention is attained via Broadbent's Filter Theory or Norman's Complex Processing Model.

II. METHODS

A. SUBJECTS

The subjects participating in the experiment were 10 male Naval officers, all students at the Naval Postgraduate School in Monterey, California. Subjects ranged in age from 27 to 37 years with an average age of 31.60 years. All subjects volunteered freely to participate in the experiment and were not compensated for their time. Prior to participation in the experiment, subjects were required to sign a Waiver of Responsibility (See Appendix B). The subjects were not informed of the purpose of the experiment, although they were told that alcohol ingestion was involved. The primary military service experience of the subjects is shown in Table II.

Military Experience	Total
Jet Pilots	4
Prop/Helo Pilots	4
Surface	3
TOTAL	10

Table II. SUBJECT BACKGROUND

B. EXPERIMENTAL DESIGN

Data from the experiment was analyzed using nonparametric statistics. In particular, the Walsh Test was used since the experiment yielded interval data, related samples (i.e. each

subject was his own control) and a small sample size [Siegel, 1956]. The Walsh Test is based upon the difference scores obtained by comparing the matched pairs of scores on each subject before and after each particular treatment. The null hypothesis to be tested here is whether these difference scores are drawn from a population whose median is zero. If the null hypothesis is rejected, then the difference scores are (on the average) other than zero is accepted, implying that the particular treatment involved had a significant effect upon performances. In the present study the two treatments involved are alcohol ingestion and motivation. In addition, by employing this nonparametric statistical test, the usual assumptions associated with parametric statistics such as independent observations, normally distributed population, and equal variance of population are not involved. The fewer assumptions which are made, the greater the generality of the results of the experiment.

The conceptual design of the experiment is presented in Figure 5.

Two different sets of scores were entered for each subject in each cell of Figure 5. The first set of scores is the percent correct data, i.e., the number of correct responses divided by the total number of responses. The second set of data is the total time taken by each subject to make 100 correct responses. Therefore, performance was evaluated on the basis of correct response percentage as well as total time to make 100 correct responses.

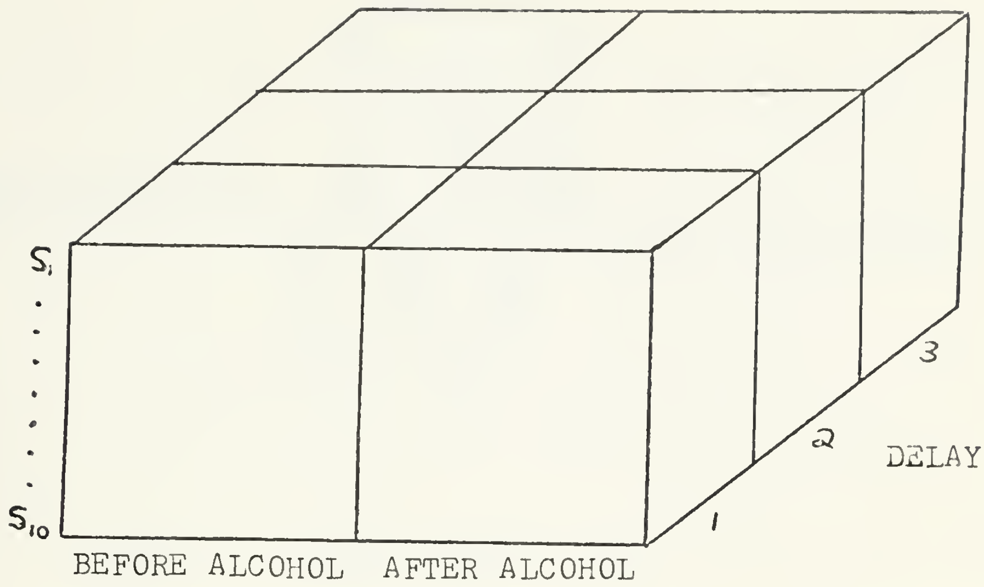

Figure 5. CONCEPTUAL DESIGN OF EXPERIMENT

C. APPARATUS

The apparatus used in this experiment was the Response Analysis Tester (RATER), Model 3, manufactured by General Dynamics Convair Division. It was designed as a psychomotor testing instrument to provide measurement of impairment of Short Term Memory via both speed and accuracy of responses to presented stimuli. The RATER gear consists of 2 primary components - the display unit and the control unit.

The display unit consists of a display window upon which the stimuli are presented, and four different response buttons, each corresponding to one of the four stimuli (plus sign, diamond, circle, and triangle). See Figure 6.

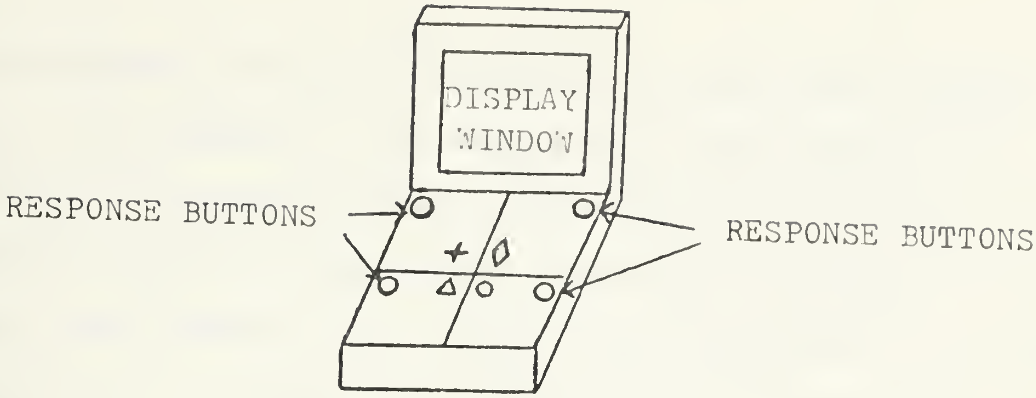

Figure 6. RATER DISPLAY UNIT

The four response buttons were clearly labeled as to their corresponding symbols. The subject's task was to respond to the symbols randomly presented in the display window by pressing the appropriate response button. Subjects were instructed to rest their thumbs and forefingers of each hand on the buttons, so that response time did not include movement time. Depressing the correct response button for the presented symbol caused the symbol to immediately be replaced by the next symbol, and one correct response would be recorded on the control unit counter. Depressing an incorrect button had no effect on the displayed symbol and one incorrect response would be recorded on the control unit counter. The symbol would always remain in the display window until the correct response button was depressed, at which time the next symbol would appear. All subjects operated the RATER display unit inside a noise reduction isolation booth.

The RATER control unit, located outside the noise reduction isolation booth, was operated by the experimentor and included

total response and correct response counters and a delay mode switch. See Figure 7. The RATER device was capable of operation in several different delay modes. In delay 0, the subjects responded to the symbol currently displayed in the window. For example, if a diamond was displayed, the correct response was to depress the response button corresponding to a diamond, at which time the next symbol would appear. This mode was only used to familiarize the subjects with the RATER apparatus.

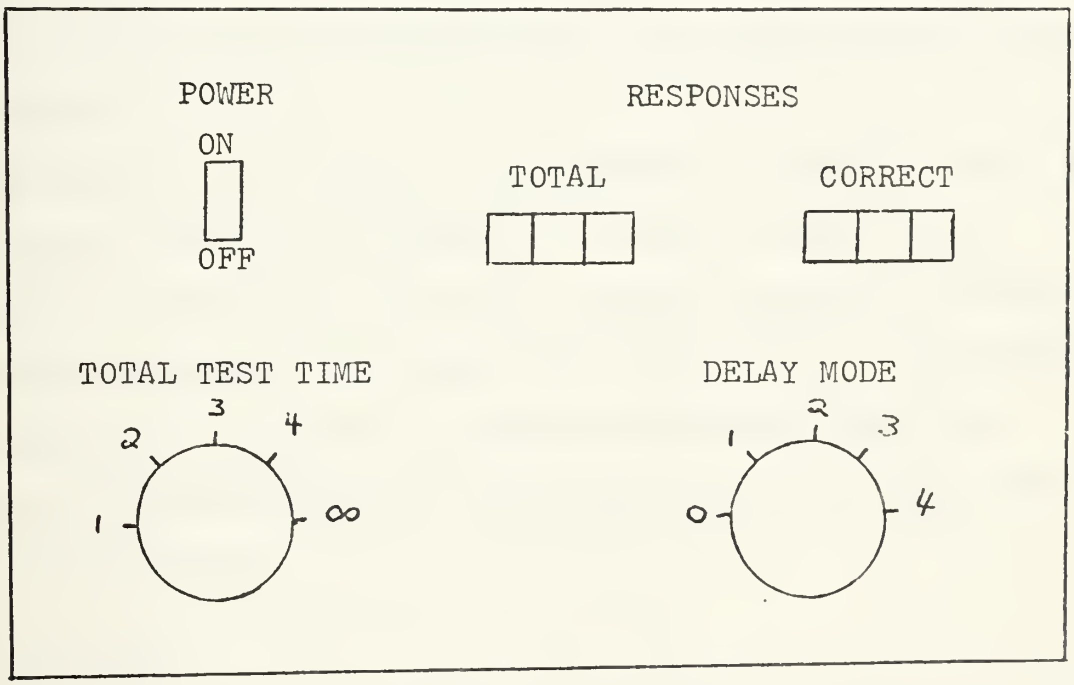

Figure 7. RATER CONTROL UNIT

In delay 1, the subject was presented a symbol for 1.5 seconds, followed by a second symbol which remained in the window until the subject responded correctly to the first symbol. In other words, the subject was instructed to repond to the symbol 1 back from the symbol that was currently being displayed.

In delay 2, the subject was presented 2 symbols, each of 1.5 seconds duration, followed by a third symbol which remained in the window until the subject responded correctly to the first symbol. In other words, the subject was instructed to respond to the symbol 2 back from the symbol that was currently being displayed.

In delay 3, the subject was presented 3 symbols, each of 1.5 seconds duration, followed by a fourth symbol which remained in the window until the subject responded correctly to the first symbol. In other words, the subject was instructed to respond to the symbol 3 back from the symbol that was currently being displayed. Only delay 1, 2, and 3 were used in the experiment.

D. PROCEDURE

Prior to running the actual experiment, all subjects were given three separate training sessions in order to familiarize themselves with the RATER device. During each training session, the subjects were read instructions (See Appendix A) prior to operation of the RATER. Each subject commenced with the delay 1 task, followed by delay 2 and concluding in delay 3.

The subjects operated in each delay mode until 100 correct responses were made. For each delay mode, the number of total responses, as well as the time required to make 100 correct responses, were recorded.

The same procedure was followed during the actual experiment. After completing the delay 1, delay 2, and delay 3 sequence, each subject was weighted and given a dosage of alcohol sufficient enough to raise their BAC to .1%, which constitutes legal drunkenness in the State of California. The dosages administered were a function of the subjects' weight, as given by the following equation from Billings, et.al. [1973] which closely estimates the expected peak blood alcohol concentration following the ingestion of alcohol.

$$BA = \frac{K \cdot C \cdot Q}{W}$$

Where BA = maximum blood alcohol concentration in mg %

K = constant = 60 in the English System

C = % concentration of alcohol in beverage

Q = quantity of beverage consumed in ounces

W = body weight in pounds

To obtain blood alcohol in percentage terms, mg % is divided by 1000. The alcohol administered was Old Stagg Bourbon, mixed with Pepsi Cola and ice. The subjects were given their dosage in the isolation booth, and were provided fifteen minutes to consume it, followed by a 20 minute waiting period to allow the alcohol to absorb into the blood stream. The subjects then performed the delay 1, delay 2, delay 3

sequence while under the influence, and the number of total responses and time to make 100 correct responses were recorded. Upon completion of this sequence, the subjects were instructed that they were to run the delay sequence once more, with a bottle of bourbon being given to the subject who performed the best, using both speed and accuracy equally weighed as the criterion.

The experimental sequence is shown in Figure 8.

Delay 1,2,3 Sequence	Alcohol Ingestion	Alcohol Absortion	Delay 1,2,3 Sequence	Delav 1,2,3 With Motivation
	15 min.	20 min.		

Figure 8. EXPERIMENTAL SEQUENCE

III. RESULTS

Analysis of obtained data using the nonparametric Walsh Test revealed significant differences in the means of the percentage of correct responses before and after alcohol ingestion at the .05 level for all 3 delay modes.

In addition, the motivation treatment was not significant in testing the means of percentage of correct responses in all 3 delay modes.

Neither alcohol ingestion nor motivation treatment had any significant effect upon the time to complete 100 correct responses in all 3 delay modes. Results are shown in Table III and Table IV, and graphically in Figure 9 and Figure 10.

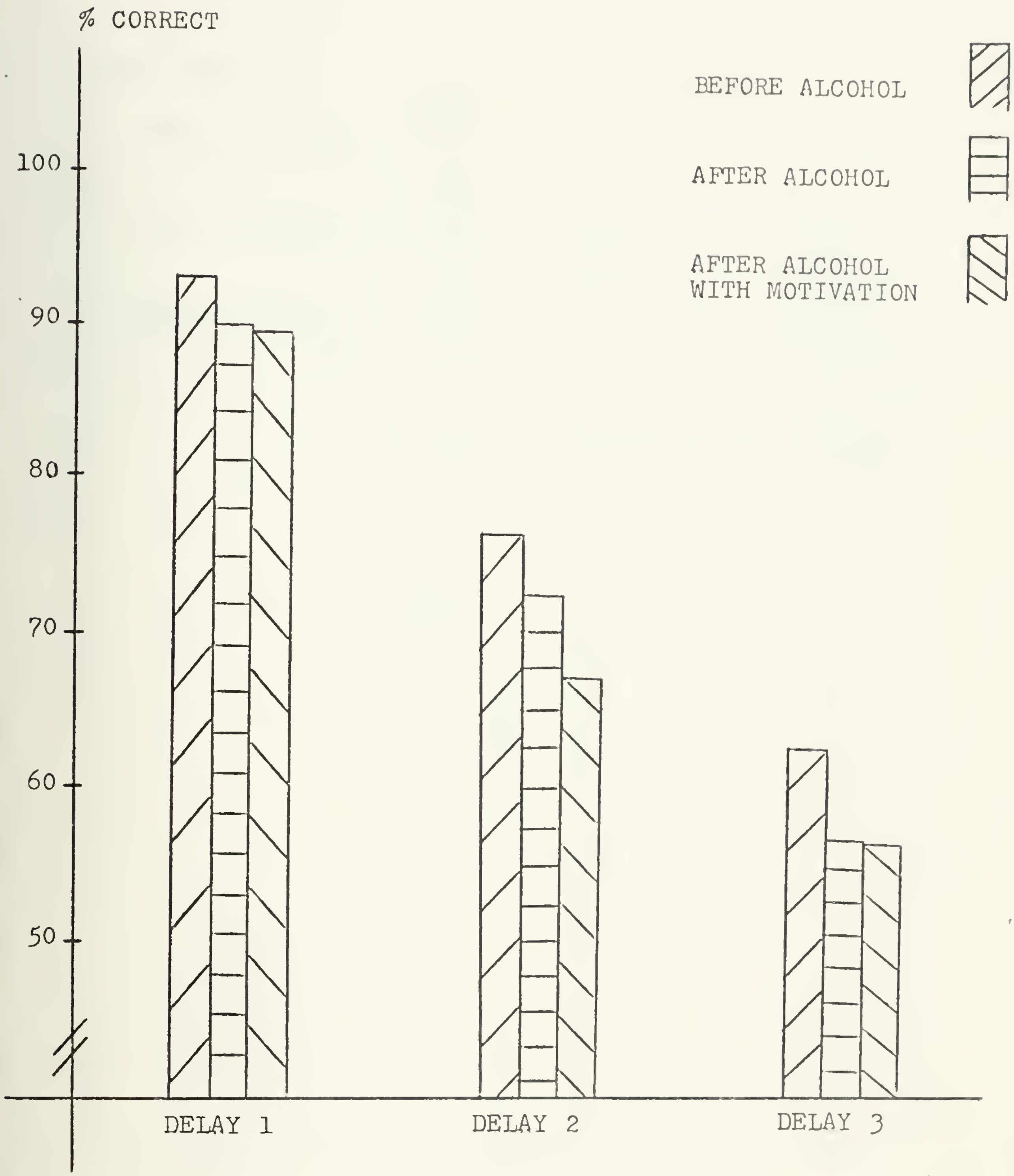

Figure 9. PERCENT CORRECT RESPONSES

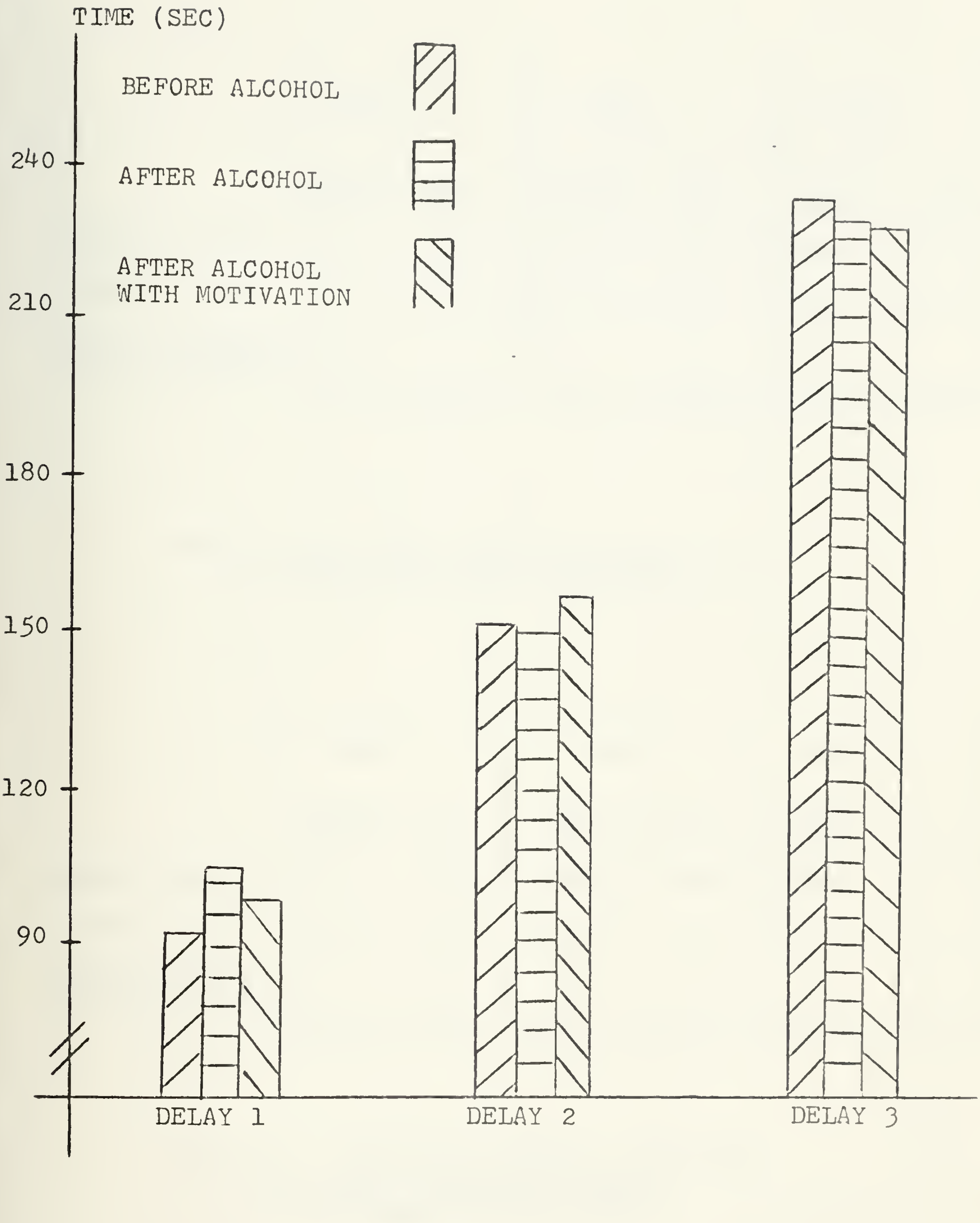

Figure 10. TIME IN SECONDS TO MAKE 100 CORRECT RESPONSES

	DELAY 1		DELAY 2		DELAY 3	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
BEFORE ALCOHOL	93.3	5.1	76.2	13.4	62.8	13.5
AFTER ALCOHOL	90.5	9.5	72.7	13.4	56.4	12.2
AFTER ALCOHOL WITH MOTIVATION	89.2	11.1	67.5	13.7	56.4	13.3

Table III. MEAN AND STANDARD DEVIATION OF PERCENT CORRECT RESPONSES

	DELAY 1		DELAY 2		DELAY 3	
	MEAN	S.D.	MEAN	S.D.	MEAN	S.D.
BEFORE ALCOHOL	92.8	43.2	152.2	73.9	233.0	124.7
AFTER ALCOHOL	103.3	45.5	150.9	53.5	229.5	93.2
AFTER ALCOHOL WITH MOTIVATION	97.2	38.7	157.7	68.1	228.8	123.0

Table IV. MEAN AND STANDARD DEVIATION OF TIME IN SECONDS TO MAKE 100 CORRECT RESPONSES

For % data: (1 TAIL)

H_0: The median differences between percentage of correct responses before alcohol and after alcohol is zero.

H_1: the percentage of correct responses before alcohol is greater than the percentage of correct responses after alcohol.

For TIME data: (1 TAIL)

H_0: the median difference between time to make 100 correct responses without motivation and with motivation is zero.

H_1: the time to make 100 correct responses without motivation is greater than the time to make 100 correct responses with motivation.

	DELAY 1		DELAY 2		DELAY 3	
	%	TIME	%	TIME	%	TIME
BEFORE / AFTER	.05	NS	.05	NS	.05	NS
AFTER / MOTIVATION	NS	NS	NS	NS	NS	NS

Table V. STATISTICAL WALSH TEST RESULTS

IV. DISCUSSION

The results of this experiment indicated a significant decrease in Short Term Memory subsequent to alcohol ingestion. These findings support the studies of Ryback, Weinert and Fozard [1970] in which they concluded that alcohol seriously impairs memory in pilots when given sequential memory tasks such as takeoff and landing checklists. Since the various delay modes of the RATER are analogous to responding to priority tasks of a sequential nature while piloting an aircraft (such as proper emergency procedures), the current findings were noteworthy. The fact that the subjects' percentage of correct responses (or accuracy) significantly decreased at the .05 level in all 3 delay modes also supports the conclusions of Billings, Wick, et.al. [1973] in their studies with instrument approaches flown after alcohol ingestion. Their findings of a narrowing of attention and decrease in channel capacity were supported by this experiment.

The time necessary to complete 100 correct responses was not significantly effected by either alcohol ingestion or motivation, while accuracy of response was degraded for each delay mode. This suggests that alcohol had little effect upon stimuli processing time, while significantly affecting the registration and retention of the presented stimuli. These results agree with those of Tamerin and Weiner [1971] who believed that alcohol "dulls perception," rendering

memory traces to be more fragile than normal, and therefore more vulnerable to being wiped out via pro-active interference from subsequent stimuli.

Although it might be expected that the subjects performance would improve (i.e. increase in percent correct responses and decrease in time to make 100 correct responses) after they were provided with motivation to create attention, no significance was present in any delay mode for either criterion. In the case of the percent correct for the delay 2 mode, had the alternative hypothesis stated that the percentage of correct responses after alcohol with motivation decreased, significance would have resulted at the .05 level. However, since this inconsistent result occurred only in the delay 2 mode, it is considered spurious and therefore connotes little importance. It is possible that this resulted from the subjects' activation level being too low as postulated by Ryback [1970]. Perhaps another reason for no difference in performance after motivation was that the bottle of bourbon offered as a reward was insufficient motivation to effect increased attention. Any studies involving alcoholic ingestion are subject to uncontrollable factors such as daily personal disposition, physical and mental states, biorhythmnic cycles, etc.

Each subject was told to stress speed and accuracy equally while performing the various delay modes of the RATER. However, it was obvious that each subject employed their own particular technique. Nevertheless, the subjects were

consistent in their techniques, and the use of a matched pairs statistical test in which each subject was his own control accounts for this technique variability and validates the data.

The subjects performance on the RATER tended to support Miller's theory of chunking. For example, in the delay 3 mode, subjects generally responded in sets of 3. They were in effect encoding bits of information according to some previously learned classification (in this case the delay mode), therefore creating more efficient usage of Short Term Memory storage.

Although it was not the intent of this experiment to compare the different delay modes, the subjects performance severely decreased as the delay mode increased, supporting Waugh and Norman's [1965] conclusions that the probability of an item in STM being recalled is a function of the number of items between stimulus presentation and attempted recall. That is, traces of previous items are written over and obliterated by subsequent traces. The difficulty encountered in delay 2 and delay 3 may also be attributed to lack of rehearsal. Since the subjects were performing under time constraints, they were denied the opportunity to adequately rehearse presented stimuli and therefore the traces were not sufficiently embedded in STM to provide recall at a later time.

For the delay 1 mode, subjects reported ease of recollection due to visual rehearsal, or encoding of stimuli according to

visual properties. Since in this mode subjects were responding to the stimuli which was immediately before presented, the visual image of the object was still quite fresh and therefore immediately recallable. Responding, therefore, to a stimuli immediately preceeding a current one apparently requires little, if any, storage process in lieu of these lingering visual traces.

The subjects experienced considerable difficulty with proactive interference. They easily responded correctly to the first few stimuli (when no interference occurred) but quickly encountered problems in simultaneously remembering presented stimuli for later use and recalling stored stimuli for present response. This phenomenon gives weight to Broadbent's single channel time sharing capacity theory. Thus, storing presented stimuli and recalling previously stored stimuli apparently are incapable of being simultaneously performed on the same channel. If attempted, obliteration of either the incoming or outgoing neural traces results, a phenomenon quite similar to the cocktail part conversations.

All subjects expressed surprise when informed that they were legally intoxicated (.1 BAC), enforcing the fact that performance and STM degradation set in long before the subjects were aware of their incapacities.

The results of this experiment indicate that a subject's STM is significantly degraded after the ingestion of alcohol and performance of any task requiring STM such as operation

of an automobile or especially an aircraft should be strictly prevented, especially in light of the fact that motivation appears to have little effect upon overcoming the degradation of STM due to alcohol ingestion.

APPENDIX A

INSTRUCTIONS TO SUBJECTS

A. GENERAL

RATER is a test of your psychomotor skill. Four different symbols (a plus sign, a circle, a triangle and a diamond) will appear in a continuous random series in the viewing window. Each of the four response buttons below the viewing window corresponds to one of the four symbols. Your task is to respond to each symbol as it appears by pressing the corresponding correct button.

When you press the correct button for the particular symbol, the symbol will dim and upon releasing the button another symbol will immediately appear. If you press an incorrect button, the symbol will not change but an error will be recorded. Continue trying to make the correct response until you obtain the dimming indication and the next symbol appears.

Try to be as fast and as accurate as you can. Press only one button at a time. If you press more than one button simultaneously, an error will be recorded automatically.

Remember that the sequence of the symbols is completely random. Runs of the same symbol may occur. Do not try to anticipate which symbol will appear next.

Place the thumb and forefinger of each hand on the response buttons. Maintain this position throughout each trial. Watch for the Ready light. A trial begins three seconds later when the Test light comes on. Begin responding when the first symbol appears and continue to respond until the Test light goes off.

B. INSTRUCTIONS TO SUBJECTS FOR DELAY 1

In the delay 1 mode, your task is to note the symbols as they are presented but to delay your response until one symbol has intervened. For example, with a one-symbol delay in the selfpace mode, a symbol will appear which you should note and remember. When the next symbol appears, your response should be the normal correct response to the previous symbol, no longer present. At the same time, note the symbol present since it will determine the correct response for the next interval. In other words, you are responding in a continuous sequence as before, except that you are delaying, or shifting, your sequences of responses by one symbol. The same principle applies for delays of two and three, which you will be instructed to perform after you have completed the delay 1 mode. To start responding in the delay 1 mode, you must view one symbol prior to your first response. In the selfpace mode, RATER presents the required number of symbols and then holds the following symbol until you make your first correct delayed response.

In the first set of trials we will do now, you are to respond to the symbol that was present just before the one that is on now. In this case the first symbol will appear and will be on for one-and-one-half seconds, followed by the second symbol. The second symbol will be displayed for an indefinite period of time until you respond correctly to the first one that was displayed. Then the third symbol will appear, and then you must respond to the second one that was on; and so on, so that you are always responding one back from the one that is presently displayed.

Do you have any questions on the next set of trials?

C. INSTRUCTIONS TO SUBJECTS FOR DELAY 2

In this next set of trials your task is to respond to the symbol that was displayed two back from the one that is currently displayed. In this case you will see the first symbol for one-and-one-half seconds, followed by the second symbol for one-and-one-half seconds, and then the third one will appear. When the third one appears you respond to the first one that was presented. And when the fourth one appears you respond to the second one that was presented; and so on, so that you are always responding two back from the one currently displayed.

You are reminded that you are to respond as accurately and as rapidly as possible. Do <u>not</u> try to emphasize either speed or accuracy, but try to work for a good combination of both.

Do you have any questions on the next set of trials?

D. INSTRUCTIONS TO SUBJECTS FOR DELAY 3

On the next set of trials you are to respond to the symbol that was present three back from the one that is currently displayed. In this case you will see the first symbol for one-and-one-half seconds, followed by the second symbol for one-and-one-half seconds, and the third symbol for one-and-one-half seconds, and then the fourth symbol will appear. When the fourth symbol is on you are to respond to the first one that was displayed. And when the fifth one comes on you respond to the second one that was displayed; and so on, so that you are always responding three back from the one that is currently displayed.

Do you have any questions on this set of instructions?

APPENDIX B

WAIVER OF RESPONSIBILITY

Monterey, Ca. Date ________

I, ______________________________, by freely agreeing to participate in an experiment by Lt. CHRISTOPHER M. GRAUERT, USN, involving the ingestion of alcohol for the purpose of testing the effect of alcohol on human performance and being provided with transportation to my quarters following said experiment, hereby and herewith agree to waive and forever release all claims, demands, damages, actions, causes of action, or suits of law or in equity against Lt. CHRISTOPHER M. GRAUERT, USN, which may now or in the future arise as a result of any injuries, losses, damages, cost and/or expenses suffered during an incident to the aforementioned experiment.

I also understand that I am under absolutely no obligation to complete the aforementioned experiment once commenced and may freely elect to cease participation at any time.

____

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The effect of alcohol ingestion on short term memory and attention.